OUTCOMES of INVASIVE CARDIAC PROCEDURES

Rhode Island
1995-1997

Jay S. Buechner, PhD
Office of Health Statistics
Rhode Island Department of Health

Michael K. Dexter, MPA
Office of Health Systems Development
Rhode Island Department of Health

Michael L. Terrin, MD, MPH
Clinical Trials & Surveys Corporation
Baltimore, Maryland

June 2000

Executive Summary

The Rhode Island Cardiac Services Registry (CSR), established in late 1994, collected information on invasive diagnostic and therapeutic cardiac procedures performed on adults (ages 18 and older) in the state's hospitals from 1995 through 1997. The procedures covered included cardiac catheterization with angiography, percutaneous transluminal coronary angioplasty (PTCA), and open heart surgical procedures, primarily coronary artery bypass grafts (CABG). Five of the state's hospitals (Kent County Memorial Hospital, Memorial Hospital of Rhode Island, Miriam Hospital, Rhode Island Hospital, and Roger Williams Medical Center) provide some or all of these types of procedures and submitted data to the Registry. This report summarizes the patient outcomes of procedures performed during the period from 1995 to 1997.

During the three-year period, a total of 17,964 angiographies, 5,955 PTCA's, and 4,685 open heart surgeries were performed, involving 17,949 patients. Rates of occurrence were determined for selected outcomes of all angiographies, all PTCAs, and for the most common type of open heart surgery, coronary artery bypass graft (CABG), when performed without other open heart procedures ("isolated" CABG).

Key findings of this report include the following:

- Statewide rates of occurrence for four major complications of angiography, including strokes, emergency CABG procedures, Q-wave myocardial infarctions, and death within 24 hours, were all less than 1 percent.

- Statewide rates of occurrence for four major complications of PTCA, including strokes, emergency CABG procedures, Q-wave myocardial infarctions, and death within 24 hours, were all less than 1 percent.

- The in-hospital mortality rate after PTCA, including all deaths during the same hospital stay as the procedure, was 1.41% in Rhode Island during 1995-1997. Comparable rates elsewhere were 0.89% in New York State (1995), 0.99% in six northern New England regional hospitals (1990-1993), and 1.66% in hospitals that participated in the American College of Cardiology's national database (1991-1996).

- Rates of occurrence for most outcomes after PTCA did not differ significantly between the two hospitals that perform PTCA, except in the case of emergency CABG, for which the rate at Rhode Island Hospital (1.0%) was higher than at Miriam Hospital (0.5%).

- The most commonly occurring major complications of isolated CABG procedures were post-operative infections, affecting 4.6% of patients undergoing the procedure. Other major complications include reoperation during the same hospital stay (3.4% of patients), death during the same hospital stay (3.0%), and stroke (1.7%).

- Rates of occurrence for two complications, reoperation and infection (at surgical sites) differed significantly at the two hospitals performing CABGs. Reoperation was more common at Miriam Hospital (3.4%) than at Rhode Island Hospital (2.0%). Surgical site infections were more common at Rhode Island (2.0%) than at Miriam (1.0%).

- The statewide in-hospital mortality rate after isolated CABG procedures was 3.0% in Rhode Island during 1995-1997. Comparable rates elsewhere were 2.5% in New York State (1996), 3.3% in New Jersey (1996-1997), 3.8% in Pennsylvania (1995), and 2.8% in hospitals that participate in the Society of Thoracic Surgeons' national database (1997).

- After risk-adjustment using New Jersey's methodology, mortality rates after isolated CABG were 3.0% at both facilities in Rhode Island that perform these procedures, Rhode Island Hospital and Miriam Hospital.

- Mortality rates for isolated CABG were higher for patients having repeat procedures (6.9%) than for patients with no prior CABG procedures (2.7%). Emergency CABG procedures were much more likely to result in death (16.9%) than CABG procedures performed on either an urgent (3.8%) or elective (1.5%) basis.

- The in-hospital mortality rate after isolated CABG was significantly lower when the procedure was performed by surgeons who perform 150 or more procedures per year (2.4%) than when performed by physicians who perform fewer than 150 procedures per year (4.6%).

TABLE OF CONTENTS

INTRODUCTION

The Rhode Island Cardiac Services Registry (CSR) was a cooperative effort of the Rhode Island Department of Health, the five hospitals in Rhode Island providing invasive cardiac diagnostic or therapeutic procedures (Kent County Memorial Hospital, Memorial Hospital of Rhode Island, Miriam Hospital, Rhode Island Hospital, and Roger Williams General Hospital), and Clinical Trials & Surveys Corporation (C-TASC) of Baltimore, Maryland. This report is the third report from the CSR; it presents information on the outcomes of invasive cardiac services provided in Rhode Island during the three-year period for which the Registry collected data, 1995 - 1997. Two previous reports (*1995 and 1995 Annual Reports of the Rhode Island Cardiac Services Registry* and *1997 Annual Report of the Rhode Island Cardiac Services Registry with 1995-1997 Trends*) presented summary information on the utilization of invasive cardiac services provided in Rhode Island and on the characteristics of patients receiving these services. This report was produced in conjunction with the Rhode Island Department of Health's Health Quality Performance Measurement and Reporting Program.

In 1994, a Cardiac Services Advisory Committee was established, including representatives of the cardiology and cardiac surgery programs at each hospital plus other interested parties. The Committee guided the process of setting goals and objectives for the Registry and selecting the contractor, C-TASC. A Subcommittee for Research and Data Dissemination was established to provide guidance to C-TASC for technical operational issues and in the production of reports made available to the public. Both the Advisory Committee and the Subcommittee included representatives from the cardiology and cardiac surgery programs and members representing third-party payers, the Brown University Medical School, and consumer groups.

After selection to serve as the data collection and analysis contractor for the registry, C-TASC staff worked with the members of the Subcommittee and Department of Health staff to develop data collection procedures and forms. C-TASC staff developed computer software for use by hospital staff to enter data onto electronic data files, and tested data collection procedures with the hospital staff. C-TASC staff also performed all data analyses in consultation with the Subcommittee and prepared the annual utilization reports and trend report for the Cardiac Services Registry.

For this report on outcomes of cardiac procedures, the Subcommittee provided guidance to the Department of Health and C-TASC on the specific outcomes to be analyzed for each procedure. All reported outcomes occurred during the same hospital stay as the procedures with which they are associated. For angiography procedures, the included outcomes are stroke, Q-wave myocardial infarction, emergency CABG, and death within 24 hours. For PTCA procedures, the included outcomes are all those for angiography plus death in the same hospital stay as the procedure. Information is also provided on the rate of use of stents in conjunction with PTCA. For CABG procedures performed without other open heart procedures ("isolated CABG"), the included outcomes are reoperation during the same hospital stay, infection at selected sites, stroke, and in-hospital death.

Since the outcomes of invasive cardiac procedures depend greatly on the severity of the patient's illness, the presence of other health conditions, and other patient risk factors, such as age, the Subcommittee explored the possibility of adjusting for differences in risk among patient populations when comparing outcomes across hospitals. Because of the small number of facilities performing these procedures in Rhode Island, it was necessary to rely on risk-adjustment methods developed from larger databases. Such methods were available only for the mortality rate after isolated CABG, and C-TASC obtained and applied the risk-adjustment method developed for use in New Jersey as the method most compatible with the CSR database.

C-TASC staff performed all data analyses on the CSR database per the Subcommittee's guidance and produced summary data for review and comment by the Subcommittee. The final report was prepared by Department of Health staff based on the results of the analyses performed by C-TASC and the comments of the Subcommittee.

RHODE ISLAND
CARDIAC SERVICES REGISTRY

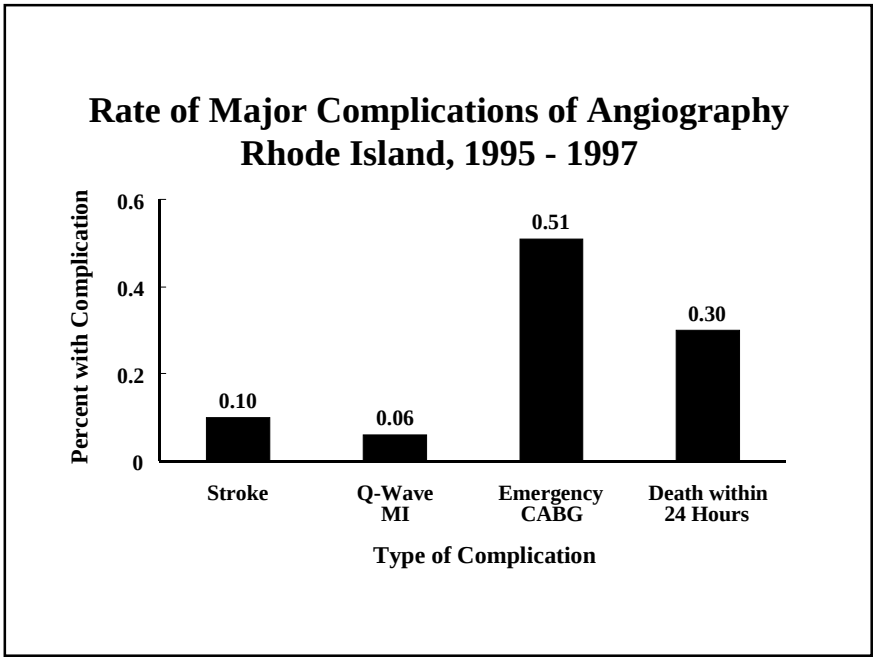
Outcome Measures
for Angiography
1995-1997

Major complications after angiography

During 1995-1997, there were 17,964 angiography procedures performed at five hospitals in Rhode Island (Kent County Memorial Hospital, Memorial Hospital of Rhode Island, Miriam Hospital, Rhode Island Hospital, and Roger Williams Medical Center). Of these, just under one-third (32.0%) were performed on an outpatient basis. Patients undergoing these procedures at the Miriam and Rhode Island Hospitals may also have undergone PTCA and/or open heart surgery procedures during the same hospital admission.

On a statewide basis, the rates of occurrence of major complications of angiography were all well below one percent. Differences between institutions in the rates of occurrence of the major complications were not statistically significant.

Complication	Kent (N = 1883) %	Memorial (N = 680) %	Miriam (N = 7049) %	Rhode Island (N = 7149) %	Roger Williams (N = 1203) %	All Hospitals (N = 17,964) %
Stroke	0.00	0.00	0.14	0.08	0.17	0.10
Q-wave MI	0.00	0.00	0.07	0.07	0.00	0.06
Emergency CABG	0.11	0.44	0.70	0.52	0.00	0.51
Death within 24 hours	0.05	0.29	0.33	0.38	0.08	0.30



RHODE ISLAND
CARDIAC SERVICES REGISTRY

Outcome Measures
for Percutaneous Transluminal Coronary Angioplasty (PTCA)
1995-1997

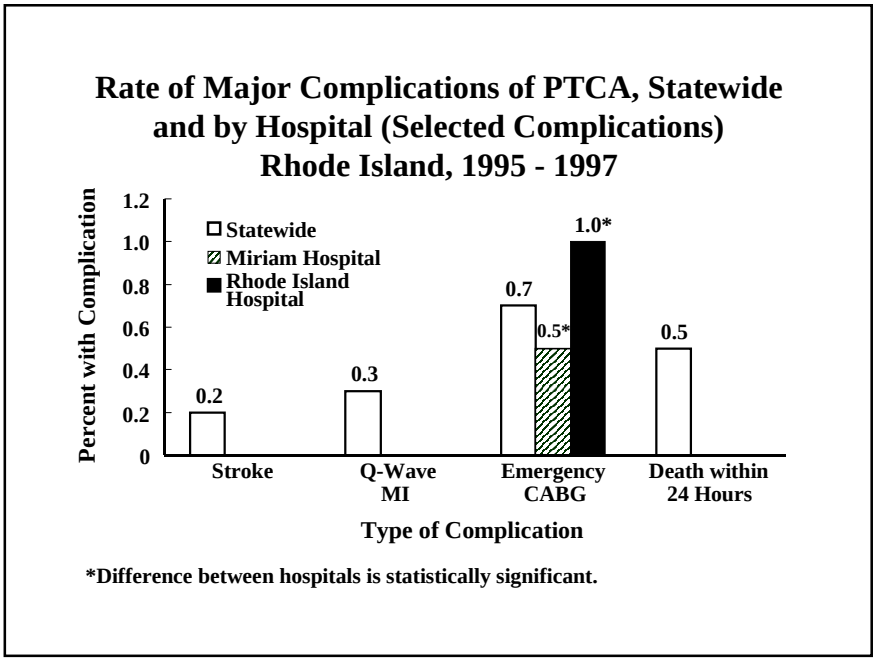
Major complications after PTCA

During 1995-1997, there were 5,955 PTCA procedures performed at two hospitals in Rhode Island (Miriam Hospital and Rhode Island Hospital). Patients undergoing these procedures may have subsequently had open-heart surgery, including CABG, during the same hospital admission.

The rates of occurrence of major complications of PTCA ranged from 0.2% for stroke to 0.7% for emergency CABG. Differences between institutions in complication rates were not statistically significant with the exception of the rate of emergency CABG, which was 1.0% at Rhode Island Hospital and 0.5% at Miriam Hospital.

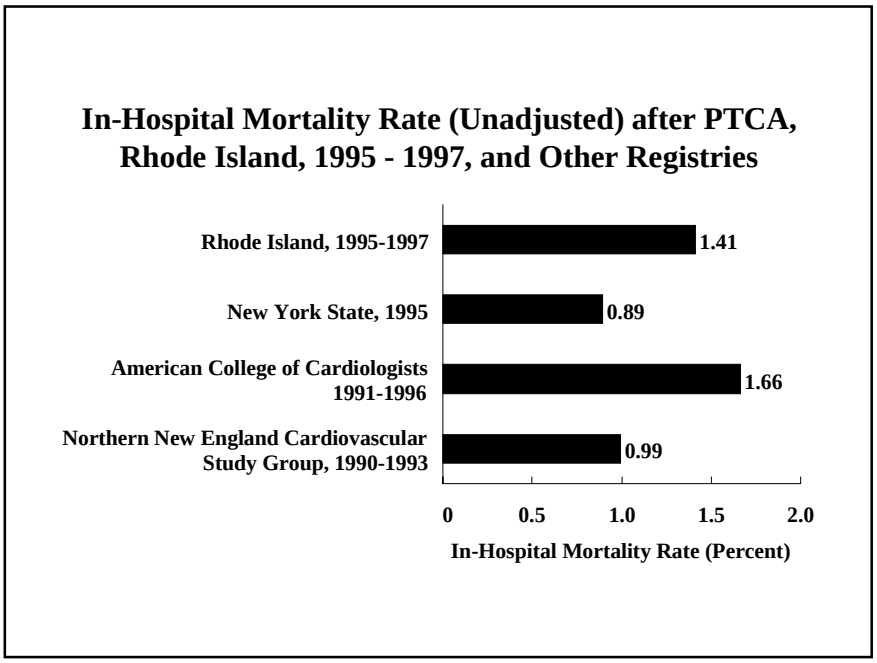
Complication	Miriam (N = 3215) %	Rhode Island (N = 2740) %	All Hospitals (N = 5955) %	Statistical Significance*
Stroke	0.22	0.11	0.17	Not significant
Q-wave MI	0.25	0.29	0.27	Not significant
Emergency CABG	0.47	1.02	0.72	Significant
Death within 24 hours	0.44	0.66	0.54	Not significant
Death in Hospital	1.59	1.20	1.41	Not significant
Death in Hospital or Emergency CABG	1.87	2.12	1.98	Not significant

*Difference between hospitals is significant at $p < 0.05$



In-hospital mortality rate after PTCA (unadjusted)

In hospitals in Rhode Island, 1.41% of PTCA patients died after their procedures but before discharge from the hospital, the majority dying more than 24 hours after their PTCA procedures. Other crude in-hospital mortality rates for PTCA were 0.89% in New York State in 1995, 1.66% during the period 1991-1996 in a national database of hospital programs operated by the American College of Cardiologists, and 0.99% in six regional hospitals in Maine, New Hampshire, Vermont, and part of Massachusetts (Northern New England Cardiovascular Study Group) during 1990-1993.



Data Sources:

New York State Department of Health. *Angioplasty in New York State, 1995*. November 1997.

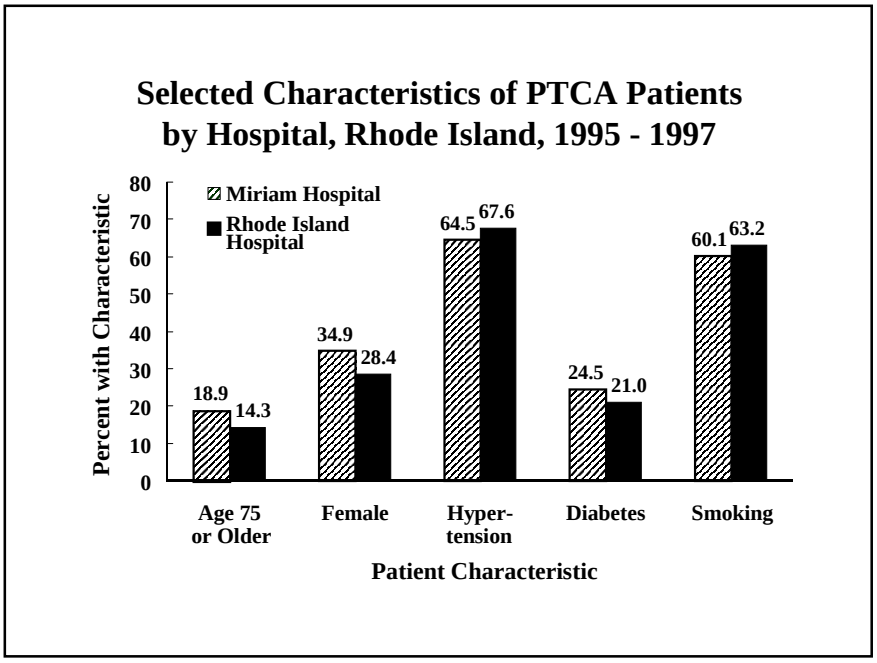
American College of Cardiology. *1996 ACC National Cardiovascular Data Registry Summary Report*. August 1996. [Covers procedures occurring between October 1991 and January 1996]

Malenka DJ, O'Rourke D, Miller MA, et al. [for the Northern New England Cardiovascular Disease Study Group]. Cause of in-patient death in 12,232 consecutive patients undergoing percutaneous transluminal coronary angioplasty. American Heart Journal 137(4):632-8. April1999.

Selected characteristics of PTCA patients

The unadjusted rates of mortality after PTCA, based on (1) death within 24 hours of procedure and (2) death anytime during the hospital stay, did not differ significantly between Rhode Island Hospital and Miriam Hospital. (See page 9.) No recognized risk-adjustment methodology exists for mortality after PTCA. However, there were significant differences ($p < 0.01$) between the two hospitals for a number of patient characteristics, including age, gender, hypertension, diabetes, and smoking history (current and former).

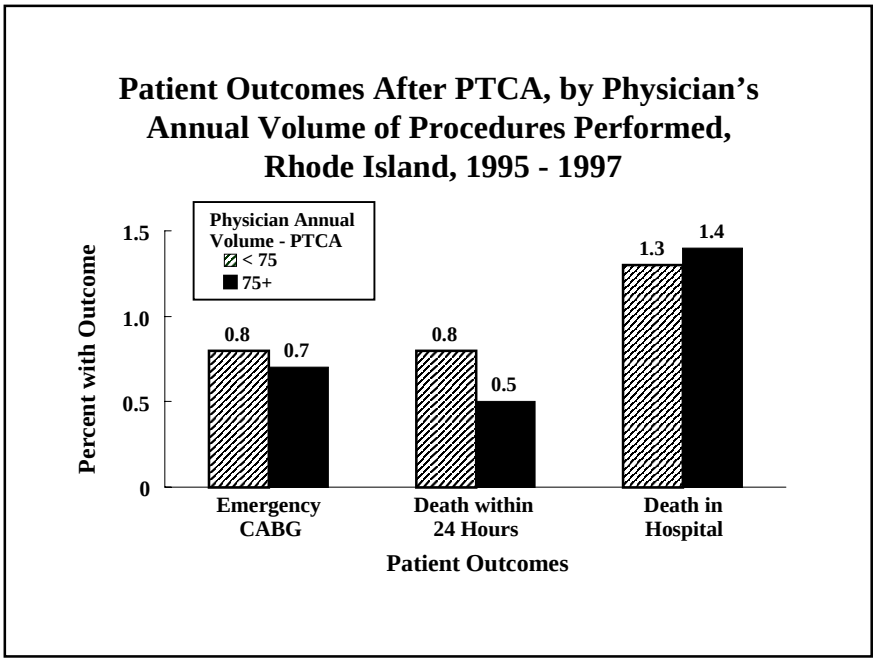
Characteristic	Miriam (N = 3215) %	Rhode Island (N = 2740 %
Age 75 or Older	18.9	14.3
Female	34.9	28.4
Hypertension	64.5	67.6
Diabetes	24.5	21.0
History of Smoking	60.1	63.2



Mortality and emergency CABG after PTCA by physician volume

The recommended level of annual physician volume for PTCA according to the American College of Cardiology is 75 or more procedures. During the three-year period covered by the Registry, fewer than 9 percent of PTCA's were performed by cardiologists with low annual volumes by this standard. In Rhode Island, no significant differences were seen in the outcomes of physicians performing below this volume level compared to physicians performing at or above this level.

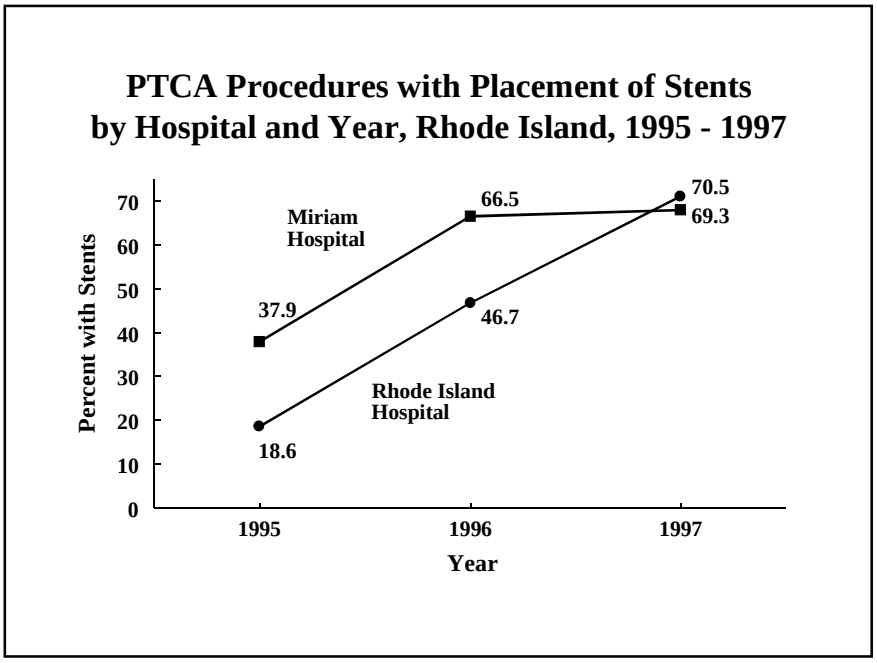
	Number of PTCA Procedures Annually by Cardiologist	
Outcome	**Fewer than 75 (N = 528)**	**75 or More (N = 5457)**
	%	**%**
Emergency CABG	0.8	0.7
Death within 24 Hours	0.8	0.5
Death in Hospital	1.3	1.4
Death within 24 Hours or Emergency CABG	1.5	1.2
Death in Hospital or Emergency CABG	2.1	2.0



Use of stents in conjunction with PTCA

PTCA has been augmented in recent years by the development of stents used in conjunction with the procedure in some patients. Stents are wire mesh tubes used to prop open an artery, usually one that has been cleared using PTCA. In certain patients, stents have been shown to reduce the arterial narrowing that occurs in 30 - 40 percent of patients after angioplasty. During 1995 and 1996, physicians at the Miriam Hospital were significantly more likely to use stents than physicians at Rhode Island Hospital. In 1997, the two hospitals used stents at approximately the same frequency.

	Miriam		Rhode Island		
Year	No. of PTCAs	% with Stents	No. of PTCAs	% with Stents	Statistical Significance
1995	891	37.9	900	18.6	Significant
1996	1092	66.5	916	46.7	Significant
1997	1233	69.3	924	70.5	Not significant



RHODE ISLAND
CARDIAC SERVICES REGISTRY

Outcome Measures
for Isolated Coronary Artery Bypass Graft (CABG) Surgery
1995-1997

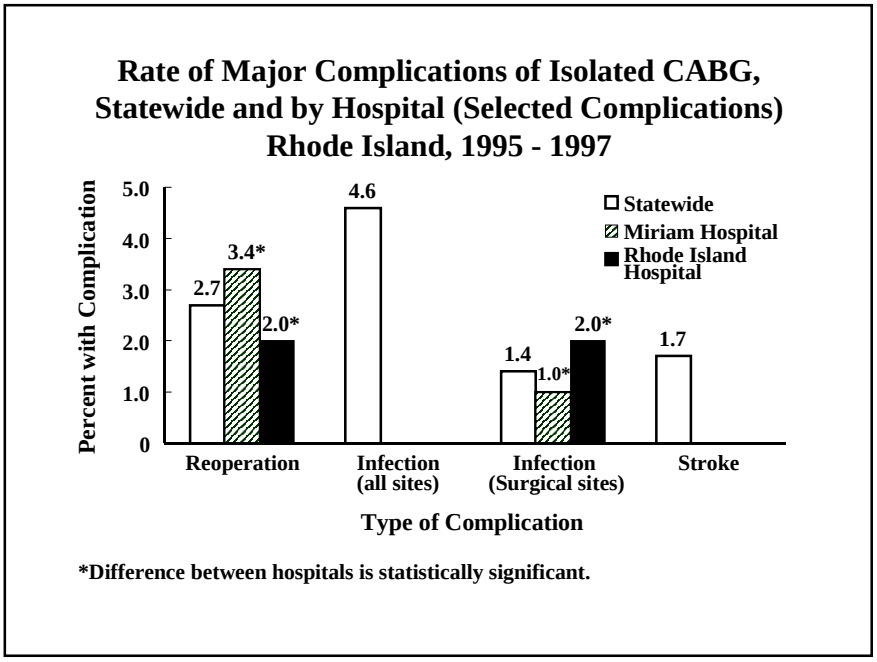
Major non-fatal complications after isolated CABG surgery

During 1995-1997, there were 3,503 “isolated” CABG procedures performed at two hospitals in Rhode Island (Miriam Hospital and Rhode Island Hospital). Isolated CABG procedures are those CABG procedures not performed in conjunction with any other open-heart surgical procedures, such as valve repairs.

On a statewide basis, the most commonly occurring major non-fatal complications of isolated CABG procedures were infections (4.6% of surgeries) and re-operation (2.7%). Differences between institutions in complication rates were statistically significant for two of the major complications, the rate of reoperation and the combined infection rate for the three direct surgical sites (superficial sternum, deep sternum, and leg).

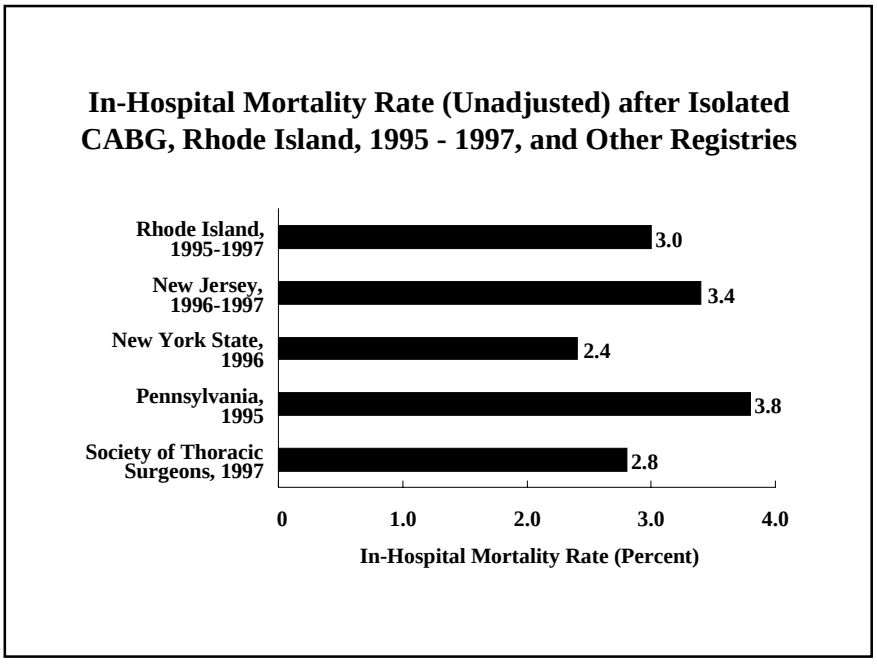
Complication	Miriam (N = 1724) (%)	Rhode Island (N = 1779) (%)	Statistical Significance*
Reoperation	(3.4)	(2.0)	Significant
Infection - all sites	(4.8)	(4.5)	Not significant
Superficial Sternum	(0.2)	(0.6)	Significant
Deep Sternum	(0.4)	(0.3)	Not significant
Leg	(0.5)	(1.1)	Significant
IABP* - Site	(0.1)	(0.1)	Not significant
Septicemia	(0.8)	(1.0)	Not significant
Urinary Tract	(3.1)	(2.0)	Not significant
Stroke	(2.0)	(1.4)	Not significant

*Difference between hospitals is significant at $p < 0.05$. IABP = intra-aortic balloon pump.



In-hospital mortality rate after isolated CABG (unadjusted)

In hospitals in Rhode Island, 3.0% of patients undergoing isolated CABG procedures died before discharge from the hospital. For comparison, the reported crude in-hospital mortality rates for isolated CABG were 3.4% in New Jersey during the period 1996-1997, 2.4% in New York State in 1996, 3.8% in Pennsylvania in 1995, and 2.8% during 1997 in a national database of hospital programs operated by the Society of Thoracic Surgeons.



Data Sources:

New York State Department of Health. *Coronary Artery Bypass Graft Surgery in New York State, 1994-1996*. October 1998.

New Jersey Department of Health and Senior Services. *Cardiac Surgery in New Jersey, 1996-1997.* March 1999.

Pennsylvania Health Care Cost Containment Council. *Pennsylvania's Guide to Coronary Artery Bypass Graft Surgery, 1994-1995*. Undated.

Society of Thoracic Surgeons. Data Analysis of the STS National Cardiac Surgery Database. January 1999. [www.sts.org/graphics/sts/db/us98/gchart53.gif]

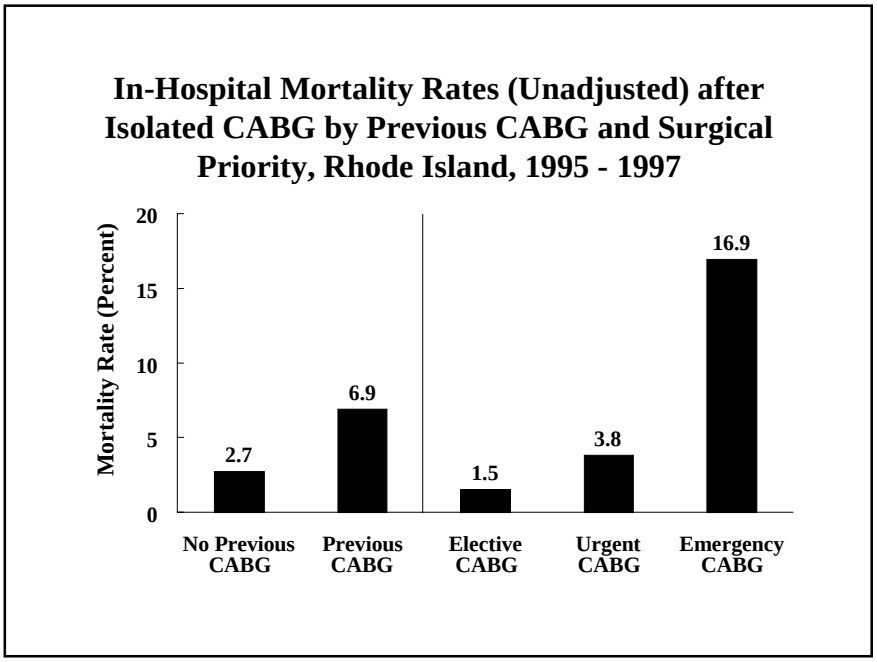
In-hospital mortality after isolated CABG, by previous CABG status and surgical priority

Patients who had had a previous CABG had mortality rates that were over 2.5 times the mortality rates for those with no previous CABG (2.7% and 6.9%, respectively).

Patients undergoing elective CABG had the lowest mortality rate (1.5%) compared to urgent CABG (3.8%) and emergency CABG (16.9%). The mortality rate for emergency CABG was over 11 times that for elective CABG, and the mortality rate for urgent CABG was 2.5 times that for elective CABG.

	Surgical Priority*							
	Elective		Urgent		Emergency		Total**	
Previous CABG Status	No. of Procs.	Percent Died	No. of Procs.	Percent Died	No. of Procs.	Percent Died	No. of Procs.	Percent Died
No Previous CABG	1978	1.3	1170	3.5	139	16.5	3287	2.7
Previous CABG	121	5.0	74	8.1	9	22.2	204	6.9
Total**	2099	1.5	1244	3.8	148	16.9	3491*	3.0

*Surgical priority is assigned by the surgeon.
*Totals exclude 12 patients (1 death) with unknown surgical priority or previous CABG status.

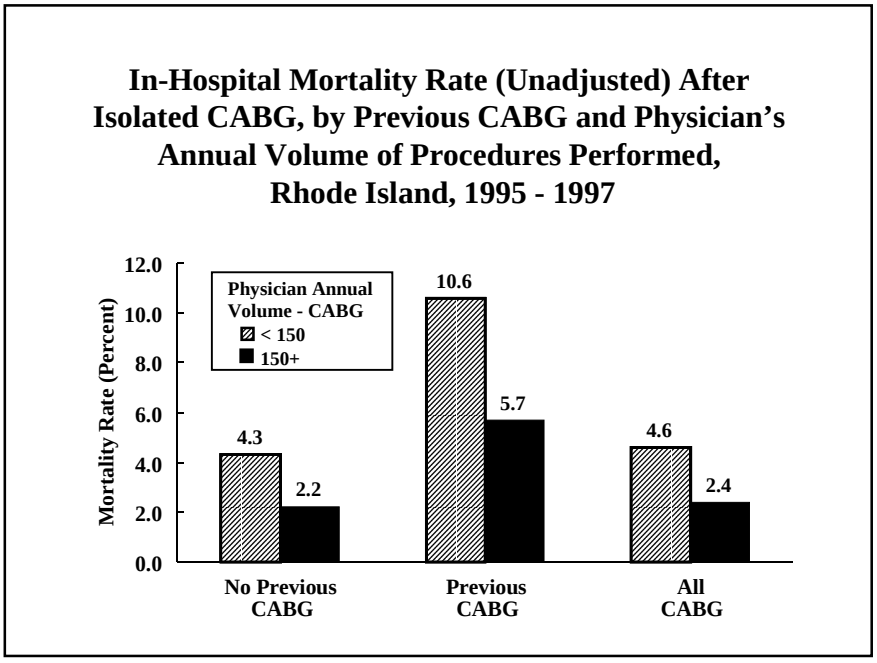


In-hospital mortality after isolated CABG by physician volume

The consensus recommended level of annual physician volume for CABG according to a review of the professional literature is 150 or more procedures, below which the quality of patient outcomes declines, on average. During the three-year period covered by the Registry, 28 percent of isolated CABG procedures were performed by cardiac surgeons with low annual volumes by this standard. As a group, physicians in Rhode Island performing fewer than the recommended number of procedures had a significantly higher crude mortality rate (4.6%) than physicians performing 150 or more procedures per year (2.4%). When only those patients with no previous CABG are included, the mortality rates were 4.3% for low-volume physicians and 2.2% for other physicians.

	Previous CABG Status					
	No Previous CABG		Previous CABG		Total*	
Number of CABG Procedures Annually by Surgeon	No. of Procs.	Percent Died	No. of Procs.	Percent Died	No. of Procs.	Percent Died
Fewer than 150	931	4.3	47	10.6	978	4.6
150 or more	2363	2.2	157	5.7	2520	2.4
Total*	3294	2.8	204	6.9	3498	3.0

*Totals exclude 5 patients (0 deaths) with unknown previous CABG status or surgeon's annual number of CABGs.

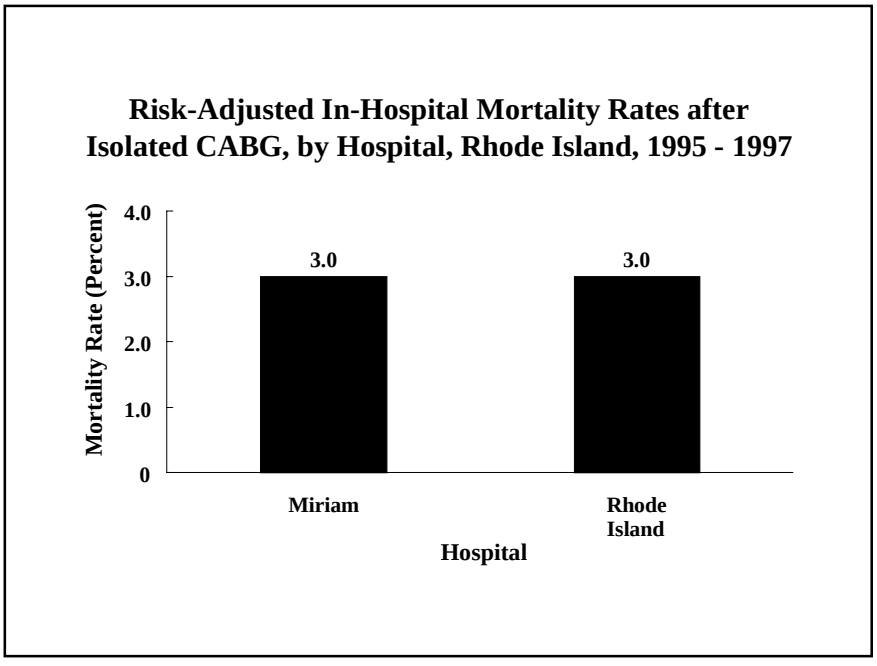


Risk-adjusted in-hospital mortality rates after isolated CABG

The crude mortality rate (not adjusted for differences in patient risk factors) for isolated CABG was higher at Miriam Hospital than at Rhode Island Hospital. Since the risk of mortality after CABG is known to vary depending on the characteristics of the patient and the severity of the patient's disease, a recognized methodology has been employed to compare mortality rates at the two institutions after adjustment for differences in known patient risk factors. (See Appendix 1. Technical Notes.) After risk-adjustment, there was no statistically significant difference between the two hospitals in the likelihood of dying after undergoing the CABG procedure (3.0% for both hospitals).

Hospital	Number of Procedures	Number of Deaths	Observed Crude Mortality Rate	Expected Mortality Rate (95% CI*)	Risk-Adjusted Mortality Rate
Miriam	1,724	63	3.7	3.6 (2.0-6.2)	3.0
Rhode Island	1,779	42	2.4	2.4 (1.4-4.2)	3.0
Total	3,503	105	3.0	3.0	3.0

*CI = Confidence Interval



APPENDICES

1. Technical Notes

2. Cardiovascular Terminology

TECHNICAL NOTES

Rhode Island Cardiac Services Registry (CSR)

A. Data file preparation

CSR hospital staff obtained lists of all invasive cardiac procedures in their hospitals from cardiology departments and surgery services. The CSR staff obtained information from departmental data files and hospital charts from medical record departments to collect data for CSR form completion. At the time of initiation of CSR data collection, the CSR staff abstracting these data ("abstractors") were trained by staff from the CSR contractor, Clinical Trials & Services Corporation (C-TASC) in form definitions and form completion procedures; data entry staff were trained in data entry procedures. In the course of the CSR data collection, abstractors were able to make inquiries concerning CSR definitions and procedures by telephone call to C-TASC and by consultation with cardiology and cardiac surgery staff in their hospitals.

In the CSR, the ORACLE™ database management system was used for data entry and to organize data in data files; the SAS™ statistical analysis system was used for data analysis. CSR forms data were keyed at the CSR hospitals into an ORACLE™ database. Data diskettes sent from CSR hospitals were updated to the main CSR ORACLE™ database at C-TASC immediately upon receipt. New data submitted on diskettes were added to the main database. Corrected data submitted on diskettes replaced the previous data on the main database. After all data for a calendar year were received (based on comparison with procedure logs) SAS™ data sets were created for analysis. The SAS™ data sets contained all data from the database except for data entry/data edit control information and patient identifying information. Each patient was assigned a unique coded identification number based on his or her Social Security number, date of birth, gender and name code. This unique number could be used to link records across hospitals and over time.

B. Data cleaning

Data edit: At the time of data entry, data were checked for out-of-range errors to be corrected before data entry could continue. When data were received at C-TASC, automated computer editing, including out-of-range and skip pattern consistency checks were performed and any errors were found reported to the CSR hospitals. CSR staff corrected the errors on the forms, entered the corrections onto the database, and sent corrected data back to C-TASC.

Monthly procedure counts: CSR hospitals were required to submit a complete count of angiographies, angioplasties and cardiac surgical procedures performed each month to C-TASC by the 10th day of the following month. Numbers of procedures by month and by hospital from the database and the logs were graphed in order to determine unusual patterns that might suggest data missing from either the logs or the database.

Physician codes: Different physician numbers were given to each physician performing cardiac procedures at each hospital based on the list of numbers used in cardiology departments and surgery departments in each hospital for third party billing. Numbers reported in the CSR database were checked against the list of correct numbers. Numbers not appearing on the list were sent back to the CSR hospitals for correction. Also, if a physician were listed as having performed a procedure that he/she did not regularly perform (e.g., a cardiac surgeon who was listed as having performed an angiography), the numbers were also sent back to the CSR

hospitals for correction. CSR hospitals were asked to provide counts of procedures according to physician from non-CSR sources (billing, operative logs, etc.) for comparison with CSR database counts to ensure that the counts of procedures by physician were correct. [Note: Physician identifiers were collected only for use by C-TASC and the CSR hospitals, and are not available to other users.]

Mortality: All reported deaths were submitted to the CSR hospitals for verification. CSR staff were asked to confirm that the death actually occurred, whether the death was temporally related to the procedure (within 24 hours for angiography and PTCA and within 30 days for surgery), and the circumstances of death. Most deaths occurring within the specified period of time were considered procedural outcomes for the purposes of the CSR. Exceptions were made in cases of angiography done prior to organ harvesting for transplantation.

Discharge dates: On CSR Form 05 (cardiac surgery) date of discharge was removed during an early revision of the form. Each year CSR staff at hospitals that perform cardiac surgery were asked to provide the discharge dates for each procedure in the CSR database. These discharge dates were independently entered into the database at C-TASC.

C. Algorithms and derived variables

[Annual] physician volume: (pages 12, 20) Number of procedures performed by a physician during a calendar year - calculated during analysis by combining data for each physician over all hospitals for each calendar year.

Hypertension: (page 11) Abstractor looks on chart for recorded systolic blood pressure of 140 mm Hg or greater or diastolic blood pressure of 90 mm Hg or greater or history of high blood pressure or treatment with anti-hypertensive medications.

D. Risk-Adjustment Methodology for Mortality after Isolated CABG

In-hospital mortality rates after isolated CABG procedures are determined by the pre-operative severity of illness of the patients undergoing this procedure as well as the quality of the care provided by surgeons and hospitals. In order to compare hospitals on the quality of care they provide, it is important to measure and adjust for differences in the overall severity of illness in the patients they treat. Because only two facilities in Rhode Island offered the CABG procedure during 1995-1997, a risk-adjustment model from a larger state or other database must be used. Of the documented models available, the risk-adjustment system employed in New Jersey for its 1996-1997 data is most adaptable to Rhode Island because it is based almost entirely on adjusting variables that were collected by the Rhode Island Cardiac Services Registry. The following description of that methodology is adapted from the publication "Cardiac Surgery in New Jersey, 1996-1997: A Technical Report" [New Jersey Department of Health and Senior Services, Trenton, NJ, March 1999].

Observed Mortality Rates: The observed mortality rate for each hospital is computed by dividing the number of patients who died in the hospital during or after isolated CABG surgery by the number of patients who underwent isolated CABG surgery.

Expected Mortality Rates: The predicted probability of death for patients undergoing isolated CABG surgery represents the chance that the patient will die during or after surgery but before discharge from the hospital and is the measure of severity of illness used in this report. The predicted probability of death is obtained using a statistical model (logistic regression) that

identifies which patient risk factors are significantly related to a patient's chance of dying during or after CABG surgery, and then assigns statistical weights to those risk factors. The weights are used in a formula that generates the patient's predicted probability of death.

The estimate of the average risk for all of a hospital's patients is obtained by summing the predicted probabilities of death for all of the hospital's CABG patients and dividing by the number of patients. This number, which is called the hospital's expected mortality rate, is an estimate of what the hospital's mortality rate would have been if the hospital's performance had been identical to the statewide performance for those patients.

Risk-Adjusted Mortality Rate: Hospital performance is assessed by comparing what actually happened (the observed mortality rate) with what was predicted to happen based on how severely ill the hospital's patients were (the expected mortality rate). First, the observed mortality rate is divided by the hospital's expected mortality rate. The ratio is then multiplied by the statewide mortality rate for 1995-1997 (3.0%) to obtain the hospital's risk-adjusted mortality rate.

The risk-adjusted mortality rate represents the best estimate, based on the associated statistical model, of what the hospital's mortality rate would have been if the hospital had a mix of patients identical to the statewide mix. Thus, the risk-adjusted mortality rate has, to the extent possible, removed differences among hospitals in patient severity of illness, since it arrives at a mortality rate for each hospital on an identical group of patients.

Interpretation of Comparative Rates: The risk-adjusted mortality rate is presented in this report as a measure of quality of care provided by hospitals. However, there are reasons that a hospital's risk-adjusted mortality rate may not accurately reflect the quality of care being provided.

First, outcome rates may vary due to chance alone. This is particularly true for low-volume hospitals, for whom very high or very low mortality rates are more likely to occur than for high-volume hospitals. Neither hospital in Rhode Island is considered a low-volume hospital with respect to isolated CABG procedures.

Differences in hospital coding of risk factors is a second possible reason that a hospital's risk-adjusted rate may not be reflective of quality of care. However, C-TASC staff monitored the quality of data submitted to the Cardiac Services Registry by reviewing and re-abstracting a sample of patients' medical records in each participating facility in each year of operation. [See the audit reports in "1995 and 1996 Annual Reports of the Rhode Island Cardiac Services Registry" and "1997 Annual Report of the Rhode Island Cardiac Services Registry with 1995-1997 Trends."]

A third reason that risk-adjusted rates may be misleading is that overall pre-procedural severity of illness may not be accurately estimated because important risk factors are missing. This is not believed to be an important consideration, however, because the Cardiac Services Registry collects a large number of risk factors that are known to be related to patient mortality from various national and international studies.

A final reason why these data may not provide a definitive measure of the quality of hospital care is that patient mortality is not the only way of measuring quality; for instance, complications of surgery, patient quality of life following surgery, and patient satisfaction are also important

markers of quality. Some of these additional measures are reported as quality-related outcomes for isolated CABG in this report.

Risk-Adjustment Model for Rhode Island: The significant pre-operative risk factors for mortality after isolated CABG surgery in 1995-1997 in Rhode Island are presented in Table A-1, along with coefficients for the statistical model, p-values, and odds ratios. The initial set of risk factors investigated was the set identified in the risk-adjustment method used in New Jersey with its 1996-1997 mortality data for isolated CABG procedures. Statistical analysis of the Rhode Island CSR data identified which of the initial set of risk factors were significant ($p < 0.05$) predictors locally, and those are listed in Table A-1.

The coefficients, p-values, and odds ratios for each risk factor in the table were calculated from logistic regression based on Rhode Island data. The coefficients can be used to compute a given patient's probability of death given the patient's risk factors. These are expressed as odds ratios for mortality relative to a reference population without the risk factor. The p-values state the level of significance for the logistic regression coefficients of each of the risk factors in Table A-1; only included are risk factors for which $p < 0.05$. The risk-adjusted mortality data presented on page 21 reflect the mortality rates for each hospital adjusted to a patient mix with the same distribution of these risk factors as Rhode Island's patient mix as a whole.

Table A-1.
Multivariate Risk Factor Equation for In-Hospital Mortality after Isolated CABG, Rhode Island, 1995-1997.

Patient Risk Factor	Logistic Regression Results		
	Coefficient	P-value	Odds Ratio
Demographic			
Age less than 65*	NA*	NA*	1.000
Age 65-69	0.8269	0.0375	2.286
Age 70-74	1.0246	0.0059	2.786
Age 75-84	1.7727	0.0001	5.887
Age 85 and over	1.5558	0.0162	4.739
Female	-0.6569	0.0019	0.518
Male*	NA*	NA*	1.000
Comorbidity			
Renal Failure with Dialysis	1.6628	0.0019	5.274
Renal Failure without Dialysis	0.9087	0.0144	2.481
No Renal Failure*	NA*	NA*	1.000
Ventricular Function			
Ejection Fraction 1-29% or Poor	1.0534	0.0162	2.867
Ejection Fraction 30% or Greater*	NA*	NA*	1.000
Operative History			
Previous Open Heart Surgery	1.1320	0.0001	3.102
No Previous Open Heart Surgery*	NA*	NA*	1.000
Procedural Features			
Preoperative Intra-Aortic Balloon Pump	1.9842	0.0001	7.273
No Preoperative IABP*	NA*	NA*	1.000
Intercept	-3.9241	0.0001	
C-statistic	0.793		

*Reference category not included in the regression equation.

[Note: "Diabetes," "Ejection Fraction 30-49% or Fair," and "Left Main Disease," variables that were significant risk factors in the adjustment of mortality rates for New Jersey hospitals and physicians, were not significant risk factors in the adjustment of mortality rates for hospitals in Rhode Island.]

Cardiovascular Terminology

Angiography is the radiographic (X-ray) imaging and filming of the circulatory system and/or cardiac structures. It is a diagnostic X-ray study of the blood vessels during which a radiopaque dye is injected into the vessels via a catheter in order to be visualized.

Coronary Artery Bypass Graft (CABG) is a surgical procedure to improve the blood supply to the heart muscle, which involves routing the heart muscle blood supply past the narrowing in the patient's coronary arteries by using vein grafts or redirecting another artery within the chest.

Isolated CABG is a CABG procedure not performed in conjunction with any other open-heart surgical procedure, such as valve repair.

Myocardial Infarction (MI) is the death of a portion of heart muscle as the result of prolonged cessation of blood flow to the area.

Percutaneous Transluminal Coronary Angioplasty (PTCA) is the inflation of a balloon tipped catheter at the site of a coronary artery narrowing to enlarge the diameter of the vessel.

Stent is a wire mesh tube used to prop open an artery.

Stroke is a sudden disruption of blood flow to the brain either by a clot or a leak in a blood vessel.

Adapted from: State of Connecticut Office of Health Care Access. *Cardiovascular Demand Needs Analysis*. September 1999.